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Temporomandibular dysfunction in patients with diabetic foot ulcers: What could be the predictors?

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Abstract

Aim: This study aimed to investigate the factors that contribute to temporomandibular dysfunction in individuals with diabetic foot ulcers.

Material and Methods: A total of 84 people were studied in the foot ulcer and control groups. Ulcer evaluation, oral health status, quality of life, mandibular functionality, pain, and oropharyngeal swallowing problems were evaluated. Multiple logistic regression and analysis structural equation modeling were performed for temporomandibular dysfunction predictors.

Results: Patients with foot ulcers had a higher incidence of oral problems and swallowing disorders (p=0.000) and a more severe temporomandibular dysfunction (p=0.010). It was observed that increasing rest pain, diabetes duration, and age by 1 unit caused temporomandibular dysfunction to increase by 0.391, 0.552, and 0.205 units, respectively. A decrease of 1 unit in temporomandibular dysfunction was found to cause a loss of 0.618 units in swallowing. Similarly, it was observed that a loss of 1 unit in temporomandibular dysfunction and swallowing values led to a reduction of 0.515 and 0.371 units in the quality of life. Longer diabetes duration increases temporomandibular dysfunction probability by 2.691 per year.

Discussion: With prolonged duration of diabetes and increasing oral health problems, it has been determined that the presence of ulceration increases temporomandibular dysfunction. Swallowing disorder, mandibular dysfunction, and decreased quality of life were detected, along with an increase in ulcer area.

Keywords

Diabetes Mellitus, Diabetic Foot Ulcer, Temporomandibular Joint, Oral Health, Complication, Quality Of Life

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Introduction

Approximately 500 million people globally are living with diabetes, and this number is expected to rise by 25% by 2030 and 51% by 2045 [1]. Neuropathy is one of the most common complications of DM, affecting over half of patients with a disease duration of 10 years or more and serving as the leading cause of foot ulcers [2]. The prevalence of foot ulcers in individuals with diabetes ranges from 3% to 13%, with a global average estimated at 6.4% [3].

Studies have shown that diabetic neuropathy can affect all parts of the nervous system, including the head and neck region. Common oral symptoms of diabetes include xerostomia, taste disturbances, dental caries, periodontal disease, fungal infections, sensory loss, numbness, and burning mouth sensation [4]. Furthermore, it has been demonstrated that the rate of complications increases with the duration of diabetes [5]. Diabetic neuropathy can lead to the loss of protective plantar sensation [6]. Studies have demonstrated that sensory and motor deficits associated with DPN contribute to gait alterations, resulting in balance impairments and an increased risk of falls [7]. Furthermore, adaptive gait patterns have been observed, particularly in individuals with diabetes suffering from ulceration, along with reduced plantar pressure sensation and postural control, negatively impacting balance [8, 9].

Studies have shown a reciprocal interaction between temporomandibular dysfunction (TMD) and body posture, where changes in mandibular position influence posture, and postural changes affect mandibular position [10, 11]. However, literature exploring the relationship between temporomandibular joint (TMJ) disorders and foot structure remains limited. Studies have shown that changes in the plantar arch, in particular, affect the masseter and temporal muscles secondarily and change posture with compensatory muscle chain activities [12, 13]. Likewise, studies have shown that gait stability is impaired by changing the position of the mandible, and the loading surface and plantar pressure of the feet change under altered occlusion conditions in individuals with TMD [14]. A study conducted with healthy individuals found that static plantar pressure was influenced by maximum mouth opening, and postural stability improved when the teeth were in maximum occlusion [15].

Based on this information, we can infer that changes in foot structure in individuals with diabetic foot ulcers (DFUs) may negatively impact the TMJ due to the biomechanical, neurophysiological, and fascial relationships outlined in the literature. However, the literature review did not find any study examining how an ulcerated foot structure affects TMJ in individuals with DM. Given this gap, the authors suggest that further research should investigate how the type, area, and duration of ulceration, which leads to changes in foot structure, correspond with alterations in the TMJ. Additionally, it is essential to examine how factors such as the duration of diabetes, oral health issues, and the status of ulceration influence TMD. Therefore, this study aims to explore the impact of ulceration type, area, and duration on jaw pain, limitations in mandibular function, TMD symptoms, swallowing, and the determinants of TMD in individuals with DFU.

Material and Methods

Study Design

The study was conducted as an observational case-control study between January and June 2023. Participants' rights were protected, and informed consent was obtained (ClinicalTrials.gov:NCT06067022).

Participants

The study group consisted of individuals aged 46-80 years diagnosed with type 2 DM and DFU, while the control group included healthy individuals aged 37-85 years without a DM diagnosis. Exclusion criteria included a Mini-Mental Test score below 24, a history of psychiatric or systemic diseases, neurological and musculoskeletal disorders, cancer, congenital anomalies, facial paralysis, recent surgeries involving the spine, abdomen, or TMJ, and treatments related to these regions within the last six months.

The sample size was calculated as 74 participants (n=37) to achieve an effect size of 0.6 with 5% Type I error, 20% Type II error, 80% statistical power, and a 95% confidence interval. A total of 84 participants were included in the study, with 42 in the DFU group and 42 in the control group. The study flowchart is given in Figure 1.

Study Protocol

In individuals with DFU, diabetes and ulcer assessments included A1C levels, diabetes duration, glycemic control, and ulcer duration and area. Ulcer area was measured using ImageJ software through the analysis of digital photographs [16], while sensory evaluation was performed using the monofilament test. Oral health assessments covered xerostomia, burning mouth syndrome, tooth loss, and oral lesions. Quality of life, mandibular function, pain, and dysfunction were evaluated using validated scales:

Ferrans&Powers Quality of Life Index Diabetes Version (FPQLI): A 68-item scale evaluating health, socioeconomic status, psychological beliefs, and overall quality of life, where higher scores indicate better quality of life [17].

Numerical Rating Scale (NRS): TMJ pain was rated on a scale from 0 (no pain) to 10 (unbearable pain).

The Mandibular Function Disorder Questionnaire (MFIQ): MFIQ is a 17-item scale with higher scores indicating greater jaw dysfunction [18].

Fonseca Anamnestic Index (FAI): A 10-item scale for TMJ disorders, with scores of 25 or above indicating the presence of dysfunction [19].

Eating Assessment Tool (EAT-10): A 10-item scale for evaluating oropharyngeal dysphagia, where total scores of 3 or higher suggest swallowing difficulties [20].

Data Analysis

Parametric variables were expressed as mean±SD, nonparametric variables as median (min-max), and categorical data as percentages.

Normality was assessed with the Shapiro-Wilk test. Group comparisons were made using Independent T, Mann-Whitney U, and Chi-Square tests. Correlations between diabetes duration, ulcer area, TMD parameters, and quality of life were analyzed with Spearman's correlation.

Multiple logistic regression analysis was applied to determine whether the relevant variables were a statistically significant determinant of TMD (FAI?25) in individuals with DFU. We calculated odds ratios (ORs), 95% confidence intervals for ORs, and Wald statistics for each independent variable. We also used the Nagelkerke R2 to determine how much of the TMD probability of the variables included in the models could be explained. The statistical significance level was determined as p<0.05.

Path analysis via Structural Equation Modeling (AMOS 23) explored relationships between TMD, swallowing disorders, quality of life, and variables such as age, ulcer area, pain, and diabetes duration. A significance level of p<0.05 was applied.

Ethical Approval

This study was approved by the Ethics Committee of Harran University (Date: 2022-11-28, No: HRÜ/22.23.34).

Results

The mean age of the DFU group was 61.31 (46-80), while the mean age of the control group was 61.88 (37-85). The frequency of burning mouth syndrome (p=0.000), xerostomia (p=0.000), oral lesions (p=0.002), and swallowing disorders (p=0.000) was significantly higher in individuals with DFU compared to healthy individuals. Although there was no significant difference in TMD frequency (p=0.297), TMD severity was higher in the DFU group (p=0.010). The DFU group scored significantly higher than the control group on NRS (p=0.010), FAI (p=0.000), EAT-10 (p=0.000), and MFQI (p=0.000) (Table 1).

In individuals with Wagner 2 ulcers, FAI (p=0.013) and EAT-10 (p=0.039) scores were significantly higher.

In individuals with ulcer duration >30 days, FAI scores were significantly higher (p=0.010).

The ulcer area showed a significant positive correlation with FAI (p=0.005), EAT-10 (p=0.046), MFIQ (p=0.036), and FPQLI (p=0.003).

Diabetes duration showed a significant positive correlation with NRS (p=0.011), FAI (p=0.000), EAT-10 (p=0.002), and MFIQ (p=0.000).

The data considered as predictors of TMD presence in individuals with DFU and found to show significant differences in earlier analyses were examined using multivariate logistic regression analysis in three models, as shown in Table 2.

Model I: For each additional year of diabetes duration, the odds of having TMD increased significantly by 2.691 times (95% CI:

Table 1. Comparison of descriptive and clinical data of individuals

		DFU N=42	Control N=42	p
Age (Years) X(SD)		61,31 (8,33)	61,88 (10,73)	,786[a]
BMI (kg/m2) X (SD)		26,99 (4,80)	28,88 (4,76)	,074[a]
Sex n (%)				
Female		21 (%50)	17 (%40,48)	,511[b]
Male		21 (%50)	25 (%59,52)	
Clinical data n (%)				
Burning mouth syndrome	Yes	22 (%52,38)	6 (%14,29)	,000[b*]
	No	20 (%47,62)	36 (%85,71)	
Dry mouth sensation	Yes	36 (%85,71)	10 (%23,81)	,000[b*]
	No	6 (%14,29)	32 (%76,19)	
Tooth loss	Yes	39 (%92,86)	35 (%83,33)	,313[b]
	No	3 (% 7,14)	7 (%16,67)	
Tooth decay	Yes	36 (%85,71)	36 (%85,71)	1,000[b]
	No	6 (%14,29)	6 (%14,29)	
Intraoral lesion	Yes	26 (%61,90)	11 (%26,19)	,002[b*]
	No	16 (%38,10)	31 (%73,81)	
Presence of TMD	FAI<25	8 (%19,05)	12 (%28,57)	,297[b]
	FAI³25	34 (%80,95)	30 (%71,43)	
TMD Severity	No TMD	8 (%19,05)	12 (%28,57)	
	Mild	14 (%33,33)	20 (%47,62)	,010[b*]
	Moderate	8 (%19,05)	9 (%21,43)	
	Severe	12 (%28,57)	1 (%2,38)	
Swallowing Disorder	EAT-10<3	5 (%11,90)	29 (%69,05)	,000[b*]
	EAT-10³3	37 (88,10)	13 (%30,95)	
		median (min-max)		
TMJ NRS (0-10)		3,00 (0-7)	0,0 (0-5)	,000[c*]
FAI (0-100)		45,00 (0-100)	30,00 (5-70)	,010[c*]
EAT-10 (0-40)		13,00 (0-37)	1,00 (0-25)	,000[c*]
MFIQ- Part 1 (0-44)		11,00 (0-38)	2,00 (0-15)	,000[c*]
Part 2 (0-24)		7,00 (0-28)	3,00 (0-13)	,000[c*]
Total (0-68)		18,00 (0-66)	5,00 (0-28)	,000[c*]

*p<0.05, a: Independent T-test, b: Chi-Square Test, c: Mann Whitney Test, X: Mean, SD: Standard Deviation, Min: Minimum, Max: Maximum, BMI: Body Mass Index, TMD: Temporomandibular Joint Dysfunction, TMJ: Temporomandibular Joint, NRS: Numerical Rating Scale, FAI: Fonseca Anamnestic Index, EAT-10: EAT-10:Eating Assessment Tool-10, MFIQ: Mandibular Function Disorder Questionnaire.

Table 2. Predictors of the presence of TMD in individuals with DFU

	OR	%95 CI	Wald	P	-2 Log likelihood	Nagelkerke R2
Model I						
TMD						
Age(years)	1,054	[,891-1,248]	0,377	0,539		
Sex (Female)	0,041	[,001-1,918]	2,647	0,104	16,746	0,703
Diabetes duration (years)	2,691	[1,120-6,467]	4,894	,027*		
Model II						
TMD						
Burning mouth syndrome (No)	8,374	[,801-87,557]	3,149	,046*		
Dry mouth (No)	3,648	[,477-27,885]	1,555	0,212	32,468	0,292
Intraoral lesion (No)	1,154	[,187-7,119]	0,024	0,877		
Model III						
TMD						
Ulcer Type(Wagner I)	1,804	[,292-11,143]	0,403	0,525		
Ulcer Duration (<30day)	11,707	[1,182-115,937]	4,422	,035*	29,468	0,39
Ulcer Area (mm2)	1,004	[,998-1,009]	1,822	0,177		

*p<0.05 Multivariate Logistic Regression Analysis, OR: Odds Ratio, CI: Confidence Interval Model fits Hosmer-Lemeshow Test: Model I: 0.995, Model II: 0.808, Model III: 0.697 Dependent Variable: Presence of TMD (FAI?25)

Table 3. Structural equation modeling

			B0	B1	SH	Test İst.	P	R2
FONSECAtotal	<---	Age	0,205	0,634	0,294	2,158	0.031	0.629
FONSECAtotal	<---	Ulcer Area	0,088	0,004	0,004	0,93	0.352	
FONSECAtotal	<---	Activity Pain	0,045	0,224	0,472	0,475	0.635	
FONSECAtotal	<---	Rest Pain	0,391	7,547	1,908	3,955	P<0.001	
FONSECAtotal	<---	Duration of Diabetes	0,552	2,136	0,383	5,58	P<0.001	
EAT10total	<---	FONSECAtotal	0,618	0,199	0,04	5,035	P<0.001	0.382
Quality of Life	<---	FONSECAtotal	-0,515	-0,1	0,023	-4,314	P<0.001	0.639
Quality of Life	<---	EAT10total	-0,371	-0,223	0,072	-3,106	P<0.001	

β0: standard coefficient; β1: non-standardized coefficient; SH: Standard Error; R2: Regression Coefficient

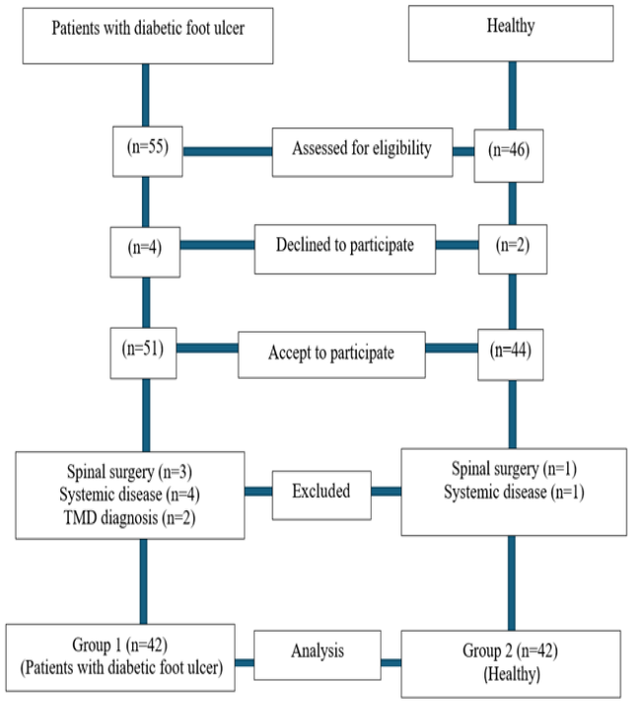

Figure 1. Study flowchart

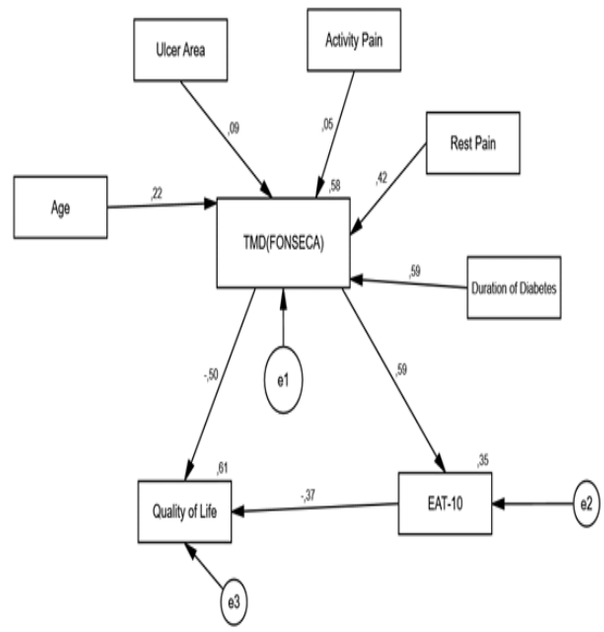

Figure 2. SEM Model Diagram (CMIN/DF(≤ 3 or 5), RMSEA(<0.08 or ≤ 0.05), CFI(> 0.95), and TLI(> 0.90) fall within the acceptable range)

1.120-6.467, p=0.027).

Model II: In individuals with burning mouth syndrome, the odds of having TMD were 8.374 times higher compared to those without the syndrome (95% CI: 0.801-87.557, p=0.046).

Model III: In individuals with ulcer duration >30 days, the risk of having TMD was 11.707 times higher compared to those with shorter ulcer durations (95% CI: 1.182-115.937, p=0.035).

In this study, a Structural Equation Model (SEM) was employed to investigate the relationship between age, ulcer area, pain (during activity and at rest), and diabetes duration with TMD. Additionally, the association of TMD with swallowing disorders and quality of life was examined. The results of the analysis indicate that the established model meets the validity criteria. These findings are shown in Figure 2.

The patients' age, ulcer area, pain during activity and rest, and diabetes duration explained 62.9% of the total FAI score, while the total FAI score explained 38.2% of the change in EAT-10. The combined evaluation of FAI and EAT-10 scores accounted for 63.9% of the change in quality of life.A one-unit increase in age results in a 0.205 unit increase in the FAI score for patients with diabetes (B = 0.205; P = 0.031). A one-unit increase in rest pain leads to a 0.391-unit change in the FAI score (B=0.391, P<0.001). With each additional year of diabetes, FAI caused a deterioration of 0.552 units (B=0.552; P<0.001). A one-unit increase in patients' FAI score results in a 0.618-unit change in EAT-10 (B=0.618; p<0.001). A unit decrease in FAI and EAT-10 scores causes a reduction of 0.515 and 0.371 units in the quality of life, respectively (B=-0.515; p<0.001; B=-0.371; p<0.001) (Table 3).

Discussion

This study aims to examine the effects of neuropathy-induced oral health problems and ulcer-related foot structural impairments on the temporomandibular joint (TMJ) from a holistic perspective using biomechanical pathways. The findings indicate that individuals with diabetic foot ulcers (DFU) have a high prevalence of oral health issues, jaw pain, mandibular dysfunction, and swallowing disorders. TMJ complaints were found to increase with greater ulcer depth, duration, and area. Additionally, the duration of diabetes, burning mouth syndrome, and the duration of ulcers were identified as significant predictors of temporomandibular disorders (TMD).

Structural Equation Modeling revealed that factors such as age, ulcer area, pain, and diabetes duration accounted for 62.9% of the variability in TMD. Furthermore, TMD and swallowing disorders explained 63.9% of the decline in quality of life.

A recent worldwide meta-analysis (29 studies with 50,112 participants) showed that the prevalence of DPN in individuals with type 2 diabetes was 31.5% [21]. Furthermore, the prevalence of DPN varies by country and can be as high as 66% [22]. Diabetic neuropathy can impact various parts of the nervous system, including the head and neck region. Common oral symptoms experienced by individuals with DM include dry mouth (xerostomia), taste disturbances, dental caries, and burning mouth syndrome. Additionally, the prevalence and severity of these complications tend to increase with a longer duration of the disease [4].

A study reported that 18.8% of individuals with DM experienced burning mouth syndrome. It was reported that 46% to 92.5% had xerostomia, and 45% to 82.5% had intraoral mucosal lesions [4]. In the present study, among individuals with DFU, 52.3% reported burning mouth syndrome, 85.7% had xerostomia, and 61.9% exhibited intraoral lesions, with these rates being higher than those observed in healthy individuals. The high prevalence of oral health issues is attributed to the long duration of diabetes. The average duration of diabetes in the study participants was 17.62 years. The high prevalence of oral health problems observed in this study is believed to be related to the longer duration of diabetes.

In the regression model that examines how burning mouth syndrome, dry mouth, and intraoral lesions influence the presence of TMD, it was found that the probability of TMD is 8.37 times higher in individuals with burning mouth syndrome. A previous study revealed that 55% of patients with burning mouth syndrome experienced persistent symptoms throughout the day, significantly impacting their quality of life. [23]. Burning mouth syndrome has a strong impact on TMJ disorder due to pain, burning, and taste changes affecting mandibular functions.

Numerous studies have shown a bidirectional interaction between mandibular position and body posture, where changes in mandibular position can affect posture and vice versa, changes in posture can influence mandibular position [10, 11]. This interaction involves not only the muscles and fascia surrounding the TMJ but also the entire body structure [24]. Specifically, alterations in the plantar arch have been shown to affect the activity of the masseter and temporal muscles, thereby altering posture. For instance, when the plantar arch flattens, mechanoreceptors are stimulated, leading to the realignment of head and neck position and the body's center of mass [12, 13]. Additionally, in healthy individuals, static plantar pressure has been found to be influenced by maximum mouth opening, and the maximum occlusion position enhances postural stability [15]. These findings suggest that changes in foot structure in individuals with DFU may negatively impact the TMJ, highlighting the need to investigate the relationship between the type, duration, and area of foot ulceration and TMJ alterations.

In this study, it was observed that individuals with deeper ulcers experienced a higher incidence of TMD. Additionally, individuals with ulcers lasting longer than thirty days exhibited higher TMD scores. Structural equation modeling analysis revealed that each unit increase in the ulcer area was associated with a 0.088 unit increase in TMD scores. When the ulcer duration exceeded thirty days, the likelihood of developing TMD increased by 11.7 times. The type, duration, and area of the ulcer are thought to affect the temporomandibular joint through changes in the foot's loading surface and plantar pressure. Particularly, extensive and deep ulcerations, as well as long-term ulcerations, may increase the risk of TMD due to adaptive gait and decreased postural control.

In this study, each year of increased diabetes duration was found to increase the risk of TMD by 2.69 times and lead to a 0.552 unit increase in TMD scores. These results emphasize the importance of effective monitoring and management of diabetes in preventing or reducing the development of TMD.

This study found that diabetes duration, ulceration, and oral health issues are significant factors in the development of TMD in individuals with DFU. Regression analyses revealed that diabetes duration was the best predictor of TMD likelihood, followed by the type, area, and duration of ulceration, as well as oral health problems. Structural equation modeling showed that increases in age, resting pain, and oral health issues were associated with higher TMD scores, which in turn were linked to a reduction in quality of life.

Conclusion

The present study found that oral health problems were common in individuals with DFU, and jaw pain, mandibular dysfunction, and swallowing disorders were high due to TMD. It was observed that TMJ complaints increased as the depth, duration, and surface area of ulceration increased, and complaints about swallowing disorders increased as the depth and area of ulceration increased. Results of this study showed that diabetes duration, burning mouth syndrome, and ulcer duration are essential determinants of TMD in individuals with DFU. When evaluating oral health problems in individuals with DFU, it may be necessary to assess them holistically, including TMD and swallowing problems. It should be considered that rehabilitation success in individuals may increase by evaluating TMD and swallowing problems, which reduce the individual's quality of life physically, psychologically, and socially in these patients.

Limitation

The most significant limitation of the present study is the lack of postural evaluation. It was necessary to evaluate the general body posture and the anterior posture of the head, primarily associated with TMD.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or compareable ethical standards.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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